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Foreign Technology Imports and Economic Growth in Developing Countries

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A developing country's economic growth rate increases as foreign technology imports increase. In developing countries, increases in productivity depend not on innovation but on importing foreign plants and equipment and on borrowing foreign technology.

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Summary findings

Zhang and Zou investigate the relationship between foreign technology imports and economic growth in developing countries.

They develop an intertemporal endogenous growth model that explicitly accepts foreign technology imports as a factor of production. The model establishes a link between the growth rate of productivity in a developing country and the country's intensity of learning to use foreign technologies.

They hypothesize that a developing country's economic growth rate increases as foreign technology imports increase.

They run regressions with data for about 50 developing countries, using different econometric methods and time spans. These empirical tests confirm the hypothesis that foreign technology transfers boost income growth rates.

Moreover, economic developing in developing countries differs from that in industrial countries. In developing countries, increases in productivity depend not on innovation but on importing foreign plants and equipment and on borrowing foreign technology.

This paper—a product of the Public Economics Division, Policy Research Department—is part of a larger effort in the department to understand economic growth and foreign trade. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Carlina Jones, room N10-063, extension 37754 (38 pages). January 1995.

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1. INTRODUCTION

The relationship between the transfer of foreign technology and economic growth in developing countries has long been studied by economists. In the gap-model approach, Chenery and Bruno (1962), McKinnon (1964), Bacha (1984), and Taylor (1990, 1993) focus on foreign exchange resources as of the most important constraint on economic growth in developing countries. Their argument is based on the idea that most developing countries, because they cannot produce the needed technology-embodied capital goods domestically, rely on imported capital goods in acquiring advanced technology; thus, imported capital goods and intermediate goods are indispensable inputs; and if there is not sufficient foreign exchange to finance the desired technology-embodied foreign capital goods and intermediate goods, the economy cannot operate properly, not to mention achieve high growth.[1]

Some economists even claim that foreign technology imports are the most important factor in explaining the rapid economic growth of Japan, Taiwan, South Korea, and other newly industrialized countries. For example, Amsden (1989, p. V) argues that the common character of the economic development process of all the "late industrializers" (i.e., developing countries) is that their industrialization is based on learning. Such countries as Japan, South Korea, Brazil, Turkey, India, and Mexico "all industrialized by borrowing foreign technology rather than by generating new

[1]Bochove (1982) also argues that many imports are indispensable inputs in developing economies, therefore imports should be treated explicitly as a factor of production in long-run growth models.

products or processes[.]" She suggests that a growth model appropriate for late industrializers should incorporate not technological innovation, but foreign technology imports.

While the idea of imports as a factor of production has been put forward in some simple models, to our knowledge, there does not exist an intertemporal endogenous growth model incorporating this idea, nor are there any systematic studies to test this hypothesis. Although many new growth models try to tackle the important issue of endogenous productivity growth, they fail to explain the important linkage between foreign technology transfer and the phenomenal economic growth in countries like Japan, South Korea, Taiwan, and many others. Thus the conventional growth model is inappropriate for developing countries because it throws away valuable information on the source of productivity increase in these countries: borrowed foreign technology through import and transfer.

On the empirical side, there are few studies based on the two-gap model approach in testing the linkage between imports and growth. For example, Esfahani (1991) conducted a simultaneous-system analysis testing the relationship among exports, intermediate imports, and economic growth using a sample of 31 semi-industrialized countries, and found that "export promotion policies in these countries can be quite valuable in supplying foreign exchange, which relieves import shortages and permits output expansion." (p. 114) However, there exists no empirical studies directly testing the hypothesis that foreign technology imports are the most important factor in explaining economic growth process in developing countries.

In this paper, we first develop an intertemporal endogenous growth model that explicitly links foreign capital imports to economic growth in developing countries. Then we conduct an empirical test on the model using a sample of about 50 developing countries.

In section 2, we present a two-goods model of optimal growth along the lines of the technology argument by dividing capital accumulation in a typical developing country into two parts: the accumulation of traditionally, home-produced capital and the accumulation of imported foreign technology. Revenues from exports are used to purchase foreign consumer goods and foreign technology imports. We formally show that a developing country's economic growth rate increases as foreign technology imports increase. In section 3, we conduct empirical tests of the hypotheses generated by the model, using panel data from developing countries. Section 4 concludes.

2. AN ENDOGENOUS GROWTH MODEL WITH FOREIGN TECHNOLOGY IMPORTS

The model developed in this section has its origins in the neoclassical growth model. The standard version of the neoclassical growth model developed first by Solow (1956) has the property that the only potential sources of growth are sustained exogenous increases in factor supplies (e.g., population growth) and exogenously given technological change (see, for example, Jones & Manuelli 1989). Thus, except for the possibility of exogenous technical change, these models of growth lead to the startling conclusion that there is no per capita growth in the long run. Rather, depending on initial conditions, there is growth until the capital stock reaches a steady state where things settle down permanently. The fundamental problem with the neoclassical growth model, as Solow (1970) acknowledged, is that it is not able to explain the wide differences in rates of productivity growth across countries. Faced with the phenomenal sustained growth in per capita output that many developing countries have experienced, the only explanation the model has to offer is exogenous technological change, which sheds no new light on cross-country differences.

Since the mid-1980s, many economists have tried to endogenize the process of technological change. Three different groups of models have been proposed to deal with this problem. The first group relies on externality and increasing returns to scale (Romer 1986). In the second group are the models of human capital formation pioneered by Lucas (1988). The third focuses on the introduction of new goods with learning by doing advanced by Grossman and Helpman (1990). However, al. of these models fail to explain the important linkage between foreign technology transfer and the phenomenal economic growth in countries such as Japan, South Korea, Taiwan, and many other developing countries. As Amsden (1989) points out, the conventional growth model is inappropriate for developing countries because it throws away valuable information on the source of productivity increase in these countries: borrowed foreign technology through import and transfer.

We construct a model that addresses this shortcoming. Two features distinguished our model from all the other growth models. First, we explicitly assume that foreign capital goods are indispensable inputs in developing countries' production. Foreign capital goods are not perfectly substitutable by home capital goods. Second, we build into the model a direct linkage between foreign technological imports and productivity increases in developing countries by assuming that the rate of technological growth is a positive function of foreign capital imports.

2.1 The Model

There are two economies in this model: the home country and the foreign country. The home country is a developing economy, and foreign country is a developed one. There are two goods -- the home good and the foreign good; and the home good price in the foreign market is P_x, which, as will be discussed later, is a negative function of the quantity exported.

At time t there are $N(t)$ identical persons in the home country producing the home good with a technology given by the production function,

$$Y(t) = K_h(t)^{\alpha} K_f(t)^{\beta} [A(t)N(t)]^{1-\alpha+\beta}, \ (a+\beta<1) \tag{1}$$

Where $K_h(t)$ is home capital stock at time t and, $K_f(t)$ is foreign capital. While allowing substitution between home capital and foreign capital in production, in general, foreign capital through its embodiment of modern technology is more efficient than home capital. The idea of putting foreign capital into the production function as an input is taken from the paper by Devarajan and Zou (1993). $N(t)$ is the total population in the home country. The population is growing at a constant rate n, i.e., $\dot{N}/N = n$.

$A(t)$ is an index of labor-augmenting technology at time t. $A(t)$ is growing at rate ϕ: $A(t) = e^{\phi t}$. We can define $N(t)e^{\phi t}$ as the effective labor force at time t, and denote it as $\hat{N}$. Thus,[2]

$$\hat{N} = N(0)e^{(n+\phi)t}, \ \ because \ N = N(0)e^{nt} \tag{2}$$

The effective labor force grows at the rate of $n + \phi$. For a given size of physical population, there will be more effective units of labor as time passes. But the number of physical bodies increases at the constant rate n. Now we can rewrite the production function as follows:

$$Y = K_h^{\alpha} K_f^{\beta} \hat{N}^{1-(\alpha+\beta)} \tag{3}$$

[2]For notational simplicity, we will drop the time index for all the current variables from here on. So unless specified otherwise, N is equivalent to $N(t)$.

Dividing both sides of (3) by $\hat{N}$, and defining $y = Y/\hat{N}$, $k_h = K_h/\hat{N}$, and $k_f = K_f/\hat{N}$, the constant return assumption implies:

$$y = k_h^{\alpha} k_f^{\beta} \tag{4}$$

Note that here y, k_h, k_f are all variables measured in effective units of labor.

Now we need to further examine the technology index $A = e^{\phi t}$. In the standard neoclassical growth model, ϕ is assumed to be exogenously given. In our model, in order to capture a stylized fact of developing countries, we assume that the technological growth rate is a function of the imported foreign capital stock, i.e.,

$$\phi_t = \begin{cases} \Phi(k_f(t-1)) & \text{if } y_h < y_f \\ \phi_f & \text{if } y_h \geq y_f \end{cases} \tag{5}$$

where $k_f(t-1)$ is the foreign capital stock measured in efficient units of labor at time t - 1, and $\Phi'(.) > 0$, $\Phi''(.) < 0$. ϕ_f is the developed country's technological growth rate, which is assumed to be exogenously given and constant for simplicity. Equation (5) says that the growth rate of the labor-augmenting technology in the developing country at time t is a positive function of the stock of imported foreign capital goods at time t - 1. This is an important assumption in our model. It establishes a direct link between foreign technology transfer and home country's technological growth.

We can identify three channels through which foreign capital import affects the growth rate of technology in developing countries: first, foreign plant and equipment investments generally embody advanced foreign technology, advanced designs and advanced management methods. More investment in importing foreign plant and equipment will raise the home country's technology by having more embodied foreign technology. Furthermore, investment in foreign plant and equipment involves training technicians in the foreign country, so a higher stock of foreign capital means a proportionally larger number of people being trained in a foreign country. The second channel by which the stock of foreign capital affects the growth rate of technology is by scale economies. A higher level of foreign capital imports makes it more likely for the home country to operate foreign technology on a scale sufficient to minimize unit costs. The third channel is through experience accumulation. How efficiently foreign technology is used will depend on the experience of the user. The higher the level of foreign capital imports, the more intensively people have to learn to operate foreign equipment, and hence the faster experience accumulates. That is to say, learning-by-doing, which is one critical aspect of learning in general, depends on the accumulation of foreign capital.

The assumption that the growth rate of technology in the developed country is exogenously fixed is for analytical simplicity. Alternatively, we could have used an endogenous growth formulation along the lines of Lucas (1988) or Grossman & Helpman (1991). However, the focus of this paper is on the developing country's "catching-up" process; what happens after the developing country becomes a developed one is not important here.

We assume that there is no foreign direct investment in the home country. To obtain foreign technology, the home country relies on its export earnings. This assumption is for simplicity; it can be relaxed without changing the results in our model. The home country's foreign earnings are:

$$E = P_x X, \tag{6}$$

where P_x is the price of the home good in the foreign market.

Let C_h and C_f be the aggregate home good consumption and foreign good consumption at time t, respectively. The dynamic equations for the accumulation of home capital and foreign capital are:

$$\dot{K}_h = K_h^{\alpha} K_f^{\beta} (e^{\phi t} N)^{1-(\alpha+\beta)} - C_h - K_h - X, \tag{8}$$

$$\dot{K}_f = P_x X - C_f - K_f. \tag{9}$$

Expressed in effective units of labor, the dynamic equations for the accumulation of home capital and foreign capital become:

$$\dot{k}_h = k_h^{\alpha} k_f^{\beta} - c_h - (n+\phi) k_h - x, \tag{10}$$

$$\dot{k}_f = P_x x - c_f - (n+\phi) k_f. \tag{11}$$

Note that we have assumed away capital depreciation for simplicity.

Consumers maximize an instantaneous utility function specified as:

$$\int_0^{\infty} [\log(C_h / N e^{\phi t}) + \theta \log(C_f / N e^{\phi t})] e^{-\rho t} dt. \tag{12}$$

The separability of utility function is also purely for analytical simplicity. The constant θ is positive and measures the preference for foreign good consumption.

Note that the utility function is defined in consumption per capita (per physical body) terms while the dynamic equations are defined in terms of consumption per effective labor unit. We can transform the utility function using the equality $C/Ne^{\phi t} = c$.

$$\int_0^{\infty} [\log c_h + \theta \log c_f]^{-\rho t} dt \tag{13}$$

The representative agent in the home country chooses c_h and c_f so as to maximize (13) subject to the dynamic constraints (10) and (11), and the initial values of home capital and foreign capital ($k_h(0)$, $k_f(0)$).

The current value Hamiltonian function is:

$$H = e^{-\rho t}\{\log c_h + \theta \log c_f + \lambda_h[k_h^{\alpha} k_f^{\beta} - c_h - x - (n+\phi)k_h]$$

$$+\lambda_f[P_x x - c_f - (n+\phi)k_f]\} \tag{14}$$

Note that although ϕ changes in each period, the representative agent takes ϕ as given because it is an externality as in Romer (1986) and Lucas (1988).

The necessary conditions for maximization are:

$$c_f = \theta P_x c_h, \tag{15}$$

$$\frac{\dot{c}_h}{c_h} = \alpha k_f^{\beta} k_h^{\alpha-1} - (n+\phi+\rho), \tag{16}$$

$$\frac{\dot{c}_f}{c_f} = \frac{c_f}{\theta c_h}\beta k_f^{\beta-1} k_h^{a} - (n+\phi+\rho), \tag{17}$$

$$\dot{k}_h = k_f^{\beta} k_h^{\alpha} - c_h - (n+\phi)k_h - x, \tag{18}$$

$$\dot{k}_f = P_x x - c_f - (n+\phi)k_f. \tag{19}$$

In the steady state, $\dot{c}_h = \dot{c}_f = \dot{k}_d = \dot{k}_f = 0$. So the necessary conditions for optimization in equilibrium are:

$$\bar{c}_f - \theta P_x \bar{c}_h = 0 \tag{20}$$

$$\alpha \bar{k}_f^{\beta} \bar{k}_h^{\alpha-1} - (n+\phi+\rho) = 0 \tag{21}$$

$$\frac{cf}{\theta c_h}\beta \bar{k}_f^{\beta-1} \bar{k}_h^{\alpha} - (n+\phi+\rho) = 0 \tag{22}$$

$$\bar{k}_h^{\alpha}\bar{k}_f^{\beta} - \bar{c}_h - (n+\phi)\bar{k}_h - x = 0 \tag{23}$$

$$P_x x - \bar{c}_f - (n+\phi)\bar{k}_f = 0 \tag{24}$$

where a bar over a variable denotes its steady-state value, and all derivatives are evaluated at the steady state.

Condition (20) gives the optimal relationship between home good consumption and foreign good consumption. Conditions (21) and (22) are the modified golden rules. Condition (23) gives the steady-state level of per effective unit of labor consumption of home good. Condition (24) says that exports is the only sources of income for purchasing the foreign consumption good and foreign capital good.

2.2 Growth rate at the steady state

We define the steady state (or balanced growth path) as the state where all the variables grow at a constant rate. Thus we rule out paths with ever increasing growth rates.

Equations (21), (22), (23), and (24) tell us that in the steady state, the consumption of home and foreign goods, and the home capital stock and foreign capital stock measured at per effective labor unit are constant, i.e.,

$$c_h = \bar{c}_h,\ c_f = \bar{c}_f,\ k_h = \bar{k}_h,\ k_f = \bar{k}_f$$

Hence the growth rates of all per effective unit of labor variables are zero. Knowing this, we can find the growth rate of all the variables measured in per capita (i.e., per physical body) from the relation between per capita variables and per effective unit variables. Taking time derivative of both sides of equation (25) and then dividing the result by (25), we get the growth rate of per capita home good consumption at steady state:

$$\frac{d(C_h/N)/dt}{C_h/N} = \phi = \Phi(\bar{k}_f) \tag{26}$$

Similarly, we can show that all the per capita variables grow at the same rate when the economy is at the steady state:

$$\frac{d(C_f/N)/dt}{C_f/N} = \frac{d(K_h/N)/dt}{K_h/N} = \frac{d(K_f/N)/dt}{K_f/N} = \frac{d(Y/N)/dt}{Y/N} = \phi = \Phi(\bar{k}_f) \tag{27}$$

Equation (26) and (27) say that in the steady state, per capita consumption of home good and foreign good, and per capita home and capital stocks, and thus per capita income, are growing at the same rate $\phi(\phi = \Phi(\bar{k}_f))$, which is determined by the steady-state foreign capital stock per effective labor unit. If a country has a higher steady-state per effective labor unit foreign capital stock, its per capita income growth rate in the steady state is higher. It is conceivable that given the right parameters the home country's growth rate can be higher than that in the developed country, i.e., $\Phi(\bar{k}_f) > \phi_f$. Then the income gap between the two countries will decrease, until the home country's per capita income level is equal to that of the foreign country at which point there will be no particular advantage of importing foreign technology and the growth rate of the home economy will be the same as the foreign country $\phi = \phi_f$. This scenario captures the essence of the catching-up experience by many late industrializers (Japan, South Korea, Taiwan, Singapore), which was based on learning and borrowing foreign technology from developed countries.

The aggregate variables of this economy—aggregate income Y, total consumptions of home good C_h and foreign good C_f, and total home capital stock K_h and foreign capital stock K_f— are all growing at the rate of $\phi+n$, until the home country's aggregate income level reaches that of the foreign country, at which point the growth rates of the two economies will converge.

The above result is a very powerful one. It links a developing country's long-run economic growth rate with its efforts in learning advanced technology from foreign technological imports. The model can explain why some developing countries succeeded in catching up with the developed countries while others lagged behind.

We pause for a moment and compare the model constructed here with all existing growth models. There are three distinctive features which set this model apart from new growth models. As mentioned in the beginning, in the existing growth theory, the growth rate of technology is either assumed to be exogenously determined (Solow, 1956), or to be determined endogenously by postulating some externality effects (Lucas 1988, Romer 1986). All of them have one thing in common: they assume away the important fact that developing countries can usually take advantage of the existing advanced technology in the developed countries by intensive learning, instead of by investing in R&D and innovation. Although in the models developed by Grossman and Helpman (1991), the technological difference between the North and South is a central focus, they model the learning process as a rather mechanical one: the North always creates new products and the South always imitates. The developing countries can never catch up and surpass the income and technological level of the developed ones. Our model is a drastic departure from growth models on technological progress. In our model, it is the quality gap between the developing country's home technology and imported technology from developed country that propels the former to catch up with the latter. Through active learning, the developing country can reduce the technological gap and eventually become a "NIC". By explicitly linking productivity growth with increases in output, our model is a long distance descendant of models developed by Kaldor (1967, 1978).

Another important feature of this model is that the steady state is given a new meaning here. In most growth models, the steady state means an ideal state existing only in the future. All developing countries are usually assumed not to be in such a state, as if the long histories of these countries do not count. In our model, we do not assume that economic growth starts from the beginning of the 20th century or the end of World War II or some arbitrary date. After all, most developing countries have several hundred years history; many even have several thousand years of civilization. If after such a long history a country is still in some mid-way to the steady state, then what is the use of studying the steady state? In our model, we postulate that all developing countries are in their steady state development. Each country's steady state per capita income is growing at a rate determined within the economic system. The different growth rates we observe are the results of each nation's different preferences and tastes (which are related to culture and history) and different foreign exchange resources.

3. EMPIRICAL TESTS OF THE RELATIONSHIP BETWEEN FOREIGN TECHNOLOGY IMPORTS AND ECONOMIC GROWTH

In this part, we conduct empirical tests on the predictions generated by the model in the previous section. We test the relationship between the economic growth rate and foreign technology imports. We first develop statistical model specifications, then discuss the data and the empirical results, and then discuss policy implications and suggestions for future research.

3.1 The Model and Statistical Specification

Our empirical model specification follows the general approach used in the study by Mankiw, Romer, and Weil (M-R-W thereafter) (1992), although we do not adopt many of their assumptions.

Let the production function be:

$$Y(t) = K(t)_h^{\alpha} K(t)_f^{\beta} (A(t)N(t))^{1-\alpha-\beta} \tag{28}$$

Let S_k be the fraction of income invested in foreign capital imports. The dynamics of the economy is given by:

$$\dot{K}(t)_h = S(t)_h Y(t) - \delta K(t)_h \tag{29}$$

$$\dot{K}(t)_f = S(t)_h Y(t) - \delta K(t)_f \tag{30}$$

Equations (29) and (30) imply that the economy converges to a steady state given by:

$$\bar{K}(t)_h = A(t)N(t)\left[\frac{S(t)_h^{1-\beta} S(t)_f^{\beta}}{\delta}\right]^{\frac{1}{1-\alpha-\beta}} \tag{31}$$

$$\bar{K}(t)_f = A(t)N(t)\left[\frac{S(t)_h^{\alpha} S(t)_f^{1-\alpha}}{\delta}\right]^{\frac{1}{1-\alpha-\beta}} \tag{32}$$

Substituting (31) and (32) into the production function, and taking logs, we get an equation for per capita income:

$$lnY(t) = lnA(t) + lnN(t) - \frac{\alpha+\beta}{1-\alpha-\beta}\ln\delta + \frac{\alpha}{1-\alpha-\beta}\ln S_h + \frac{\beta}{1-\alpha-\beta}\ln S_f \tag{33}$$

Equation (33) relates a country's level of income with the rate of home capital investment and that of foreign capital investment, and its population. This equation will be the basis of our empirical study. Our model predicts that the coefficients on home capital investment and on foreign capital import are positive, and the latter should be bigger than the former in magnitude. We have to first make assumptions on the parameters before we can test the model. We assume that δ is country specific but constant over time within the same country. Thus by taking first differences of individual country observations over time we can eliminate the δ:

$$lnY_t - lnY_{t-1} = [lnA(t) - lnA(t-1)] + \frac{\alpha}{1-\alpha-\beta}(lnS_{h,t} - lnS_{h,t-1}) + \frac{\beta}{1-\alpha-\beta}(lnS_{f,t} - lnS_{f,t-1}) + [lnN(t) - lnN(t-1)] \tag{34}$$

i.e.,

$$\frac{\dot{Y}}{Y} = [lnA(t) - lnA(t-1)] + \frac{\alpha}{1-\alpha-\beta}\left[\frac{\dot{S}_h}{S_h}\right] + \frac{\beta}{1-\alpha-\beta}\left[\frac{\dot{S}_f}{S_f}\right] + \frac{\dot{N}}{N} \tag{35}$$

The term A(.) in equation (35) is in fact an all encompassing variable. It reflects not only technology, but also many unobservable factors. These include resource endowments, climates, social institutions, and other random effects. In M-R-W's study, they assume that

$$lnA(t) = \alpha + \epsilon \tag{36}$$

where α is assumed to be a constant both cross-country and over time, and ϵ is a random shock including all country-specific factors that are independent of the rate of investment and population growth. In growth form, their assumption means:

$$LnA(t) - lnA(t-1) = \epsilon_t - \epsilon_{t-1} \tag{37}$$

That is, all the unobserved institutional variables are assumed away in this formulation. This assumption allows them to proceed with the simple OLS estimation.

M-R-W provide three reasons for this assumption. First, this assumption is made not only by Solow, but also in many other growth models. They also argue that in models where investment is endogenous but preferences are isoleastic, S_h and S_f are independent of ϵ. Second, this assumption is necessary for testing different hypothese in their paper. Third, because the model predictions are very precise, they can use the result to test whether the OLS is a mis-specification.

Many economists have questioned this assumption and the three supporting arguments. For example, Islam (1992) argues that investment and fertility behavior is apparently affected by the variables included in the $A(t)$. Indeed a theoretical case can be made against M-R-W's assumption. By standard formulation, $lnA(t) - lnA(t - 1)$ is the technical growth rate ϕ, which is country specific. In fact, ϕ can be decomposed into:

$$\phi = \lambda C_i + \mu_{it} \tag{38}$$

Where i denotes countries in the sample, t is index for time. C_i is a country-specific constant, and μ_{it} is all the unobserved variables that are not correlated with the explanatory variables, and is i.i.d. with variance equal to σ_{μ}^{2}. Substituting (37) and (38) into equation (35), we have:

$$\frac{\dot{Y}}{Y} = \lambda C_i + \frac{\alpha}{1-\alpha-\beta}\left[\frac{\dot{S}_h}{S_h}\right] + \frac{\beta}{1-\alpha-\beta}\left[\frac{\dot{S}_f}{S_f}\right] + \frac{\dot{N}}{N} + \mu_{it} \tag{39}$$

Equation (39) specifies a model with heterogeneous intercepts, homogeneous slopes. If this specification is true, then M-R-W's specification of an independent ϵ is equivalent to a restriction that all intercepts are the same. And their estimates would be biased.

In what follows, we will use the specification in equation (39) to study the relationship between a country's level of income and its foreign capital import share in GDP, albeit expressed in growth rate form. The dependent variable is the income growth rate, the independent variables are the growth rates of the share of foreign capital imports in GDP, of home investment is share in GDP, and of population. The term C_t is an unobservable constant for each country. We will use variable-intercept models with panel data to deal with this issue. By assuming that the effects of the numerous omitted country-specific variables are each individually unimportant but collectively significant and possess the property of a random variable that is uncorrelated with all other included and excluded variables, we can specify our model as having common slopes for all countries but the intercept varies over individual countries. This method is called the variable-intercept method.[3]

We will also run simple OLS regressions based on M-R-W's assumption and compare the results from different methods, which would provide a test on their assumption.

3.2 The Data and Samples

The data are assembled from the United Nations Statistical Office, the World Bank, Summers and Heston (1991), and some other sources. Definitions for all variables and data sources appear in Appendix 1. The data do not include OECD countries, since many development economists argue that the development process in developing countries is different from that of developed countries. We also exclude major oil producers from our sample (as defined by World Bank in World Development Report). Countries with a population less than 1 million in early 1980s are excluded the sample because the determination of their real income may be dominated by idiosyncratic factors.

The data include annual variables and cover the period of 1965-1988. The panel data set allows us to conduct tests based on variable-intercept models, which can control for unobserved country-specific effects. We measure S_f as the share of current foreign capital goods imports in current GDP. The data on foreign capital imports are obtained from the United Nation's

[3]See Hsiao (1986) for the details of the variable-intercept method in panel regression.

International Trade Statistics.[4] S_h is calculated as the difference between the share of current total investment in current GDP minus S_f. The data on current total investment share in GDP are from the Summers and Heston (1991) data set. We measure $\dot{S}_f/S_f$ as changes in the share of foreign capital import in GDP, $\dot{S}_h/S_h$ the change in the share of home investment in GDP. $\dot{Y}/Y$ is real annual growth rate of GDP, which are from the World Bank's World Tables (1990). The population growth rate $\dot{N}/N$ is from the population data in the 1990 World Tables. Table 1 lists all the countries in our sample and the mean values of $\dot{S}_f/S_f$, $\dot{S}_h/S_h$, $\dot{Y}/Y$, *and* $\dot{N}/N$. We also list the quality rating of the data by Summers and Heston, since many of our variables are taken from their data set. This information should be useful in helping readers make judgement on the reliability of the statistical inferences from the data.

The number of developing countries included in our empirical study varies among different model specifications, depending on the variables included in a specification. Some countries may not have information on certain important variables so we have to exclude them from a particular equation.

3.3 The Result

3.3.1 Initial regressions

Table 2 presents three different regressions of the growth rate of income on the growth rate of foreign capital import, growth rate of home investment, and growth rate of population. Before

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[4]We divide the SITC two digit level import commodity data into three main categories: capital equipment imports (including SITC commodities 71,72, 73, part of 86, 87, and part of 9), intermediate good import (including SITC commodities 2, 3, 4, 5, 6, and part of 9), and final consumption good import (including commodities in the SITC groups 0, 1, 81-85, part of 86, 89, and part of 9).

Table 1: The list of Countries In the Sample
(All the variables are averages over the period 1965-1988)

Country	$\dot{S}_f / S_f$	$\dot{S}_h / S_h$	$\dot{Y} / Y$	$\dot{N} / N$	Data Quality
Greece	0.071	0.186	0.041	0.007	a-
Portugal	0.065	0.176	0.043	0.004	a-
Israel	0.098	0.152	0.052	0.024	b
Hong Kong	0.144	0.060	0.079	0.020	b-
South Korea	0.051	0.223	0.086	0.018	b-
Kenya	0.043	0.101	0.052	0.038	c
Costa Rica	0.050	0.097	0.045	0.026	c
Dominican Rep.	0.036	0.138	0.014	0.025	c
El Salvador	0.031	0.045	0.021	0.023	c
Guatemala	0.027	0.059	0.035	0.028	c
Honduras	0.058	0.077	0.016	0.033	c
Jamaica	0.051	0.106	-0.002	0.014	c
Mexico	0.023	0.178	0.046	0.027	c
Panama	0.060	0.176	0.050	0.024	c
Argentina	0.021	0.097	0.021	0.015	c
Bolivia	0.049	0.119	0.023	0.025	c
Chile	0.038	0.089	0.024	0.017	c
Colombia	0.023	0.143	0.045	0.022	c
Ecuador	0.045	0.205	0.025	0.028	c
Paraguay	0.043	0.081	0.027	0.029	c
Peru	0.034	0.124	0.028	0.026	c
India	0.007	0.163	0.037	0.022	c
Indonesia	0.027	0.195	0.060	0.022	c
Malaysia	0.075	0.227	0.064	0.025	c
Philippines	0.025	0.171	0.042	0.027	c
Singapore	0.179	0.105	0.109	0.019	c
Turkey	0.019	0.201	0.051	0.024	c

(Continued)

Table 1: The list of Countries In the Sample
(All the variables are averages over the period 1965-1988)

Country	$\dot{S_f} / S_f$	$\dot{S_h} / S_h$	$\dot{Y} / Y$	$\dot{N} / N$	Data Quality
Cameroon	0.047	0.059	0.052	0.027	c-
Ivory Coast	0.063	0.044	0.049	0.040	c-
Morocco	0.034	0.060	0.043	0.025	c-
Senegal	0.045	0.028	0.021	0.026	c-
South Africa	0.084	0.192	0.008	0.022	c-
Tanzania	0.067	0.156	0.033	0.033	c-
Brazil	0.011	0.179	0.059	0.024	c-
Uruguay	0.024	0.146	0.011	0.004	c-
Pakistan	0.016	0.119	0.056	0.030	c-
Sri Lanka	0.015	0.202	0.044	0.018	c-
Thailand	0.028	0.129	0.065	0.025	c-
Egypt	0.041	0.022	0.055	0.024	d+
Ethiopia	0.023	0.023	0.024	0.026	d+
Madacascar	0.030	0.057	0.012	0.027	d+
Malawi	0.038	0.092	0.045	0.032	d+
Mali	0.035	0.035	0.038	0.022	d+
Mauritius	0.037	0.094	0.052	0.014	d+
Sierra Leon	0.017	0.001	-0.031	0.021	d+
Zambia	0.106	0.240	0.013	0.030	d+
Ghana	0.042	0.029	0.007	0.024	d
Sudan	0.026	-0.008	0.028	0.027	d
Uganda	0.112	-0.072	0.003	0.026	d
Zaire	0.063	0.030	0.001	0.029	d
Haiti	0.014	0.063	0.035	0.018	d
Nacaragua	0.031	0.146	0.009	0.030	d

Table 2: Panel Data Regressions (Annual Data)

Dependent variable: annual growth rate of income

Method of Estimate	Pooled OLS	Fixed-effects	Random-effects
Countries:	53	53	53
Observations:	989	989	989
$\dot{S}_f/S_f$	0.059 (0.007)	0.051 (0.006)	0.053 (0.006)
$\dot{S}_h/S_f$	0.012 (0.004)	0.013 (0.004)	0.013 (0.004)
$\dot{N}/N$	0.421 (0.169)	0.529 (0.311)	0.430 (0.240)
C	0.033 (0.004)		0.032 (0.006)
R^2	0.090	0.088	0.085
$\bar{R}^2$	0.087	0.034	0.031
Test of Restrictions:		$F(52,933)=4.33$	$X^2(3)=17.00$

Note: Standard errors are in parenthesis.

we discuss empirical findings, we explain the different econometric methods used in the three regressions. The first column is the result from a simple OLS regression using pooled data. The second and third columns are results from panel data regressions using variable-intercepts method. The difference between the second column and the third column is that we use a fixed-effects model for the regression in the second column, and a random-effects model in the third. That is, in the second column, we assume that the omitted country-specific variable (C_i) are fixed over time, while in the third column regression we treat the country-specific effects, like the error term, as random variables. Generally the two types of specifications produce quite different results.[5]

At the bottom of the third column, we provide the chi-square statistic which can be used to test whether the data favor a fixed-effects model or a random-effects one. The null hypothesis is that the true model is a random-effects model. If the computed chi-square statistic is larger than the critical value at a predetermined significance level, the null hypothesis should be rejected. From Table 2 we see the computed Chi-square statistic is 17.0, which well exceeds the critical value for the 1 percent significance level at 3 degrees of freedom, which is 11.34. Thus we should reject the random-effects specification in the third column and accept the fixed-effects model in the second column. At the bottom of the second column, we also provide the F-statistic for testing the hypothesis that the intercepts for different countries are different (i.e., the pooled OLS model is mis-specified). The computed F value is 4.33, which is much larger than the 1 percent critical value. This indicates that the pooled OLS regression, which is based on the M-R-W's assumption, is indeed mis-specified. We should reject the result in column one and accept the result from the second column. However, if we look at the estimated coefficients across Table 2, we find that, econometric theory notwithstanding, the results from all the different regression are very similar. That, is to say, the pooled regression produces results similar to the panel data regression.

Now consider at the estimated coefficients. Both estimated coefficients on foreign capital imports and home investment are positive and statistically very significant. Furthermore, the estimated coefficient on foreign capital imports is indeed much higher than the one on domestic

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[5]For a detailed discussion about the difference between fixed effects and random effects models, see Hsiao 1986.

capital investment, as is predicted by our model. Thus the empirical data from 53 countries shows that the level of foreign capital imports has a positive impact on the growth rate of income. The estimated coefficient on the population growth rate is positive but not statistically significant in the fixed-effects model (the second column of Table 2), which is the favored model.

Although the results from Table 2 produce the right signs for the coefficients on the investment of foreign capital equipment and that of home capital, there are several problems. First, as mentioned above, the estimated coefficient on population growth turns out to be insignificant. Second, the magnitudes of the estimated coefficients on the three variables ($\dot{S}_f/S_f, \dot{S}_h/S_h,$ *and* $\dot{N}/N$) are too small. The implied α and β, which are the relative share of home capital and imported capital in production, are smaller than 0.02 and 0.06 respectively. And the estimated coefficient on population growth is also much smaller than 1, as the model predicted. The third problem is that the independent variables in all three regressions explain very little of the variation of the dependent variable, as indicated by the extremely low $\bar{R}^2s$.[6]

3.3.2 Omitted variable problem

We suspect that the above problems may arise because of the many omitted variables. As mentioned in the last section, our model specification are based on strong neoclassical assumptions that are not true in the real world. In reality, the economic development process in developing countries is affected not only by factors of production, but also by many social and institutional factors. These omitted variables may cause biased estimates in our model.

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[6]Please note that the smaller $\bar{R}^2s$ in the variable-intercept models are due to the fact that a large number of constants are used in these models.

Thus, in Table 3, we present the regression results with more exogenous variables included in the model. The new variables introduced into the regressions are: annual inflation rate (INFLAT), black market foreign exchange rate premium (EXCHPREM), changes in the terms of trade (TOT), primary school enrollment rate in the population (SCHOOL), growth rate of export (EXPORT).

All these variables are widely used by other economists in empirical studies growth. Fischer (1993) has argued that the inflation rate is a good measure of the long-run economic growth rate, because it is the best indicator of the overall ability of the government to manage and stabilize the economy. If macroeconomic stability is good for growth, then a high inflation rate tends to lower growth rate. Levine and Renelt (1992) show that high growth countries are also lower inflation countries, and have lower black market exchange rate premia. The negative impact of adverse terms of trade shocks on developing countries's economic growth has been a widely accepted fact. The inclusion of the SCHOOL variable was introduced first by M-R-W (1992), and has become a standard variable in growth studies ever since. Many studies have found a positive relationship between the growth rate of export and economic growth. Zhang (1994) found that different sectors of export (i.e., primary exports and manufacturing exports) have different impacts on the long-run growth rate. However, because we do not have annual sectoral cross-country data on developing countries' exports, we will only use a single export variable in this study.

Now we look at the results in Table 3. It once again contains three regressions. The first one is the simple OLS regression, and the last two are panel data regressions. Note that the sample size of regressions in Table 3 are smaller than these in Table 2. Nine countries which were in the Table 2 sample do not have information on some of the new variables, so they are excluded in Table 3 regressions.

Table 3: Panel Data Regressions (Annual Data) With Added Variables

Dependent variable: annual growth rate of income			
Method of Estimate	Pooled OLS	Fixed-effects	Random-effects
$\dot{S}_f/S_f$	0.058 (0.007)	0.058 (0.007)	0.058 (0.007)
$\dot{S}_f/S_f\ (t-1)$	0.024 (0.007)	0.023 (0.007)	0.024 (0.007)
$\dot{S}_f/S_f\ (t-2)$	0.017 (0.007)	0.016 (0.007)	0.016 (0.007)
$\dot{S}_f/S_f\ (t-3)$	0.011 (0.007)	0.007 (0.007)	0.010 (0.007)
$\dot{S}_h/S_h$	0.017 (0.004)	0.016 (0.004)	0.016 (0.004)
$\dot{N}/N$	0.901 (0.2176)	1.170 (0.510)	0.908 (0.271)
INFLAT	-0.023 (0.005)	-0.023 (0.006)	-0.024 (0.005)
EXCHPREM	-0.022 (0.005)	-0.010 (0.004)	-0.014 (0.004)
TOT	0.030 (0.011)	0.028 (0.011)	0.030 (0.011)
SCHOOL	0.00008 (0.00008)	-0.00027 (0.0002)	-0.00004 (0.0001)
EXPORT	0.056 (0.009)	0.045 (0.009)	0.051 (0.009)
DEASIA	0.005 (0.006)		0.006 (0.008)
DSASIA	0.0006 (0.007)		0.0005 (0.010)
DLATIN	-0.0097 (0.0052)		-0.009 (0.007)
DSAFRIC	-0.017 (0.006)		-0.018 (0.008)
C	0.025 (0.010)		0.028 (0.013)
R^2	0.325	0.262	0.286
$\bar{R}^2$	0.310	0.192	0.218
Countries:	44	44	44
Observations:	772	772	772
Test of Restrictions:		$F(43,614)=1.96$	$X^2(16)=28.37$

Note: Standard errors are in parenthesis.

The F and chi-square statistics are shown at the bottom of the table. The F-test once again rejects the pooled OLS regression in favor of variable-intercept models. The chi-square statistic, however, indicates that the fixed-effects model should be rejected in favor of the random-effects model. But once again we find similarities among the results in the three regressions.

Results in Table 3 show several improvements over the regressions in Table 2. First, after introducing new explanatory variables, both R^2 *and* $\bar{R}^2$ are indeed much higher than the corresponding regressions excluding new variables. Second, the estimated coefficients on population growth ($\dot{N}/N$) are very significant and close to 1 in magnitude in all three regressions. The estimated coefficients on the other key variables — foreign capital imports and home investment — are again positive and very significant, and are larger than those in Table 2 in magnitude.

All the newly added variables except the SCHOOL variable have the expected signs and are statistically significant. The SCHOOL variable is a proxy for human capital, which should be positively contributing to growth. But in Table 3, the SCHOOL variable is either insignificant (first column), or has a wrong sign (in the second and third columns). One possible reason for this result is that primary-school enrollment rate in a country is not a good proxy for the measurement of human capital.[7]

We also include several lagged foreign capital imports as exogenous variables in the Table 3 regressions. The estimated coefficients for these lagged foreign capital imports provide a very interesting result. They show that the current change in foreign capital imports has the strongest positive impact on income growth, and the impacts become weaker as one goes back further. This can also serve as a test of the causal relationship between income growth and foreign capital imports.

[7]This negative sign has appeared in many other recent studies; see Jorgenson and Fraumeni (1992) and Benhabib and Spiegel (1994) for more discussions.

Since both one-year and two-year lagged foreign capital investment have positive impacts on income growth, the causal relationship is likely to be from the former to the latter, rather than the other way around.

Finally, notice that we put regional dummy variables for different regions in the equation (East Asia, South Asia, Latin America, and Sub-Saharan Africa).[8] The countries in the base group are non-OECD European countries (Greece, Portugal, Turkey), North African countries (Egypt, Morocco), and South Africa and Israel. Table 3 shows that only the coefficient for Sub-Saharan Region is significantly negative.

3.3.3 Annual data vs. longer time span

Although Table 3 results show a significant improvement than those in Table 2, there remains the problem that the estimated coefficients on the growth rate of foreign capital imports and on that of home capital investment are still too small in magnitude. Furthermore, the reported R^2's are still not very high relative to the ones in other similar studies (for example, see Levine and Renelt 1992).

We suspect that the problem may arise from the use of the annual data, which contain too much noise and short term disturbances that do not reflect long-run trends, and are not captured in the exogenous variables in the model. One way to smooth these short term disturbances is to use a longer time span. We thus divide the total period of 1965-88 into several 5-year time intervals. More specifically, we will have four observations for each country, i.e., 1970, 1975, 1980, and 1985. When t = 1985, t — 1 is 1980. All the growth rate variables are averages over the five year time span. This set-up would also reduce the serial correlation between the μ_{it}'s.

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[8]The fixed-effects model does not provide estimates for regional dummies because the fixed individual country-specific intercepts already account for these individual country effects.

Table 4: Panel Data Regressions (5-Year Time Interval)

Dependent variable: 5-year average growth rate of income			
Method of Estimate	Pooled OLS	Fixed-effects	Random-effects
$\dot{S}_f/S_f$	0.165 (0.020)	0.147 (0.016)	0.155 (0.015)
$\dot{S}_h/S_h$	0.024 (0.019)	0.051 (0.020)	0.030 (0.016)
$\dot{N}/N$	0.715 (0.271)	1.207 (0.533)	0.833 (0.312)
C	0.026 (0.007)		0.023 (0.080)
R^2	0.400	0.609	0.498
$\bar{R}^2$	0.385	0.335	0.147
Countries:	49	49	49
Observations:	125	125	125
Test of Restrictions:		$F(48,73)=3.29$	$X^2(3)=5.52$

Note: Standard errors are in parenthesis.

Table 4 presents the regression results using 5-year time interval data. The regressions in Table 4 use the basic model without added variables, corresponding to these in Table 2. The first apparent result in Table 4 is that the R^2's are improved greatly compared to the corresponding results in Table 2 or even the larger-variable regressions in Table 3. The second thing to notice is that how once again similar the estimates from the three regressions are.

The most important result in Table 4 regressions is that the estimated coefficients on $\dot{S}_f/S_f$ *and* $\dot{S}_h/S_h$ are not only positive and very significant, they are also much larger in magnitude than those estimated with annual data.

Table 5 shows the fixed-effects panel data regressions using 5-year time intervals data with different groups of added explanatory variables. Since we have seen in all the previous tables that the results from fixed-effects model and random-effects model are very similar, we do not present the results from the random-effects regressions. Again, all the estimated coefficients on foreign capital imports are positive and significant. This result strongly supports our model prediction that foreign technology transfer is one of the most important factors in explaining the different economic growth rates among developing countries.

For comparison, in Table 6, we present the pooled OLS regressions with the same exogenous variables as in Table 5. One can see that the results in Table 6 are very similar in those in Table 5. Thus we have demonstrated that for practical purposes, pooled regressions produce results similar to results from panel regressions.

4. CONCLUSIONS

In summary, we first developed a model specification that links the growth rate of income with that of foreign capital imports' share in GDP and home investment's share in GDP. Then we ran regressions with a sample of around 50 developing countries, using different econometric methods and different time spans. Several conclusions can be drawn from this study. First, our empirical tests confirm our theoretical model prediction that foreign technology transfer has a positive impact on the income growth rate in developing counties. All the results confirm the hypothesis that foreign technology imports are a key element in explaining the differences in the growth rates of income among developing countries. The economic development process in developing countries is different from that in developed countries. More specifically, the increases

Table 5: Fixed-Effects Panel Data Regressions (5-Year Time Interval)

Dependent variable: 5-year average growth rate of income					
$\dot{S}_f / S_f$	0.132	0.111	0.115	0.102	0.197
	(0.016)	(0.018)	(0.017)	(0.018)	(0.036)
$\dot{S}_h / S_h$	0.037	0.027	0.036	0.028	0.030
	(0.019)	(0.018)	(0.019)	(0.018)	(0.017)
$\dot{N} / N$	1.107	0.819	1.157	1.394	2.260
	(0.559)	(0.492)	(0.596)	(0.643)	(1.140)
INFLAT	-0.036	-0.020		-0.021	0.004
	(0.011)	(0.011)		(0.012)	(0.016)
EXCHPREM	-0.021	-0.028		-0.024	-0.012
	(0.010)	(0.009)		(0.010)	(0.019)
TOT	0.031			-0.051	-0.124
	(0.046)			(0.045)	(0.063)
F.CONSUM		-0.011		-0.004	-0.018
		(0.015)		(0.016)	(0.018)
GDP(t — 1)		-0.000009	-0.00001	-0.00002	-0.000003
		(0.000004)	(0.000004)	(0.000006)	0.00001
SCHOOL			-0.0003	-0.0002	-0.0002
			(0.0003)	(0.00032)	(0.0004)
EXPORT			0.060	0.040	-0.012
			(0.030)	(0.030)	(0.019)
$\dot{S}_f / S_f\ (t-1)$					0.120
					(0.032)
R^2	0.721	0.735	0.681	0.794	0.926
$\bar{R}^2$	0.495	0.518	0.439	0.562	0.634
Countries:	42	44	46	40	37
Observations:	106	112	119	101	65
Test of Restrictions:	F(41,58) =2.81	F(43,61) =3.26	F(45,67) =2.61	F(39,47) =1.83	F(36,12) =1.91

Note: Standard errors are in parenthesis.

Table 6: <u>Pooled OLS Regressions (5-Year Time Interval)</u>

Dependent variable: 5-year average growth rate of income

$\dot{S}_f / S_f$	0.137	0.135	0.126	0.113	0.145
	(0.018)	(0.020)	(0.019)	(0.017)	(0.021)
$\dot{S}_h / S_h$	0.047	0.032	0.050	0.039	0.028
	(0.029)	(0.020)	(0.019)	(0.017)	(0.016)
$\dot{N} / N$	0.717	0.805	1.076	0.948	.998
	(0.250)	(0.265)	(0.282)	(0.287)	(0.338)
INFLAT	-0.027	-0.031		-0.025	-0.022
	(0.009)	(0.010)		(0.009)	(0.009)
EXCHPREM	-0.028	-0.028		-0.014	-0.014
	(0.008)	(0.009)		(0.009)	(0.010)
TOT	-0.013			-0.0003	-0.018
	(0.044)			(0.039)	(0.050)
F.CONSUM		0.019		-0.0003	-0.036
		(0.018)		(0.016)	(0.020)
GDP$(t-1)$		0.000002	-0.000002	-0.000006	-0.000004
		(0.000002)	(0.000002)	(0.000002)	(0.000003)
SCHOOL			0.0002	-0.0002	-0.00009
			(0.00009)	(0.00010)	(0.0001)
EXPORT			0.150	0.124	0.146
			(0.028)	(0.027)	(0.038)
$\dot{S}_f / S_f\ (t-1)$					0.054
					(0.024)
DEASIA				0.0016	-0.0003
				(0.0067)	(0.007)
DSASIA				-0.0027	-0.010
				(0.0076)	(0.008)
DLATIN				-0.0022	-0.012
				(0.0057)	(0.006)
DSAFRIC				-(0.0149)	-0.022
				(0.0067)	(0.007)
C	0.036	0.033	-0.0056	0.022	0.026
	(0.007)	(0.009)	(0.011)	(0.013)	(0.015)
R^2	0.582	0.579	0.563	0.744	0.842
$\bar{R}^2$	0.557	0.550	0.540	0.703	0.793
Countries:	42	44	46	49	37
Observations:	106	112	119	101	65

Note: Standard errors are in parenthesis.

of productivity in developing countries do not rely on innovation but on importing foreign plant and equipment and on borrowing foreign technology. Second, although econometric theory shows that M-R-W's OLS assumption would produce a biased result, for all practical purpose, OLS regression results are as good as panel regression results. However, one thing to note is that in all our regressions, the *F*-tests demonstrate that although the heterogeneous intercept and homogeneous slopes specification is a better model than the simple OLS, it should be rejected in favor of models allowed for hetergeneity of intercept and slopes. That is, the data call for individual country regressions. However, since we do not have enough observations for each country to allow individual country regressions, this is a candidate for future study of the relationship between income growth and foreign technology imports.

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APPENDIX I

Definitions and Sources of Variables

$\dot{Y}/Y$: Average annual growth rate of GDP. Source: World Tables, World Bank, 1992.

$\dot{S}_f / S_f$: Average annual change of the share of foreign capital import in GDP. This variable is calculated based on data from two sources: data on the dollar value of foreign capital are from United Nations' International Trade Statistical Yearbook; and the share of total import in GDP is from Summers and Heston (1991).

$\dot{S}_h / S_h$: Average annual change of the share of home investment in GDP. This is calculated as the log difference of share of home investment in GDP, and the share of home investment in GDP in turn in calculated by subtracting S_f from the share of total investment in GDP. The latter is from Summers and Heston data set.

$\dot{N} / N$: Average annual growth rate of population. Source: Summers and Heston data set.

INFLAT: Average annual inflation rate, computed as the log-difference of CPI. Source: *International Financial Statistics*, CD-ROM, June, 1993. GDP deflator data from the World Bank were used to extend inflation series for Malawi.

EXCPREM: Average black market exchange rate premium. Source: World Bank, *World Development Report*, 1991. [Computer file]

TOT: Change in terms of trade, calculated as the log difference of the net terms of trade in a time period. Sources: World Bank, *World Development Report*, 1991 dataset.

F.CONSUM: Annual average change in the share of foreign consumption import in GDP. Sources: UN's International Trade Statistical Yearbook, and Summers and Heston.

GDP(t-1): Real GDP 5 years before current 5-year period. This variable is used here as an substitution for the initial GDP level in Mankiw's single period regression model. Source: Summers and Heston (1991).

SCHOOL: Primary school enrollment as percentage of age group. Source: same as above.

EXPORT: Average annual growth rate of export, weighted by the share of export in GDP. Source: Summers and Heston.

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